WATERSHED MONITORING AND MODELING TECHNIQUES

Billy G. Turner[1], Clifford J. Arnett[2], and Mark Boner[3]

AUTHORS: [1]President, [2]Senior Vice President, Columbus Water Works, 1421 Veterans Parkway, Columbus, Georgia 31901-1600; and [3]Vice President, WWETCO, Wet Weather Engineering & Technology, LLC, 1825 2nd Avenue, Columbus, Georgia 31901.
REFERENCE: Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, the University of Georgia, Athens, Georgia.

Abstract. The Columbus Water Works has implemented a three-year program to study water quality in the Middle Chattahoochee River Watershed. The goals of the study include the protection of drinking water supplies and the general health of the watershed. Several methodologies used in the conduct of the study have transferable applications and are being delineated for dissemination to the public. The study is generating data necessary to shape future water quality standards and economical methodologies to measure the health and progress of watershed management.

INTRODUCTION

The watershed program was implemented through a partnership effort involving federal and interstate policy makers, local governments and businesses, universities, environmental organizations and the general public. The purpose of the study is to develop methodologies to understand, predict, prioritize and measure mitigative progress at addressing wet weather water quality problems and protecting drinking water supplies.

The intended contribution is to provide the environmental and land use communities assistance with regulatory and stewardship programs, including:

- Source Water Assessment and Protection
- NPDES Compliance Monitoring and Reporting
- Total Maximum Daily Load (TMDL) Assessments and Allocations
- Quantity and Quality Measurement Techniques for Watershed and Stormwater Planning
- Combined Sewer Overflow (CSO) Technology Performance for Long Term Control Planning
- Wet Weather Watershed Monitoring and BASINS Model Calibration
- Water Quality Standards Interpretation and Measurements Under Wet Weather Conditions

The State of Georgia is leading the nation in many respects toward the implementation of several of these programs. Either because of stringent CSO legislation, or interstate compacts on water rights, or environmental litigation on TMDL allocations, Georgia is breaking ground in the development of regional and national guidance. The Middle Chattahoochee River Water Quality Programs are providing some of this guidance towards improving water resources management.

Information from the watershed program is being peer reviewed by a team of national experts coordinated by the Water Environment Research Foundation (WERF) and is being disseminated through multiple outreach vehicles including workshops, newsletter articles, journal publications, flyers and brochures and through an internet project web site, www.wwetco.com. The US EPA is providing quality assurance coordination for the project.

BACKGROUND AND RELATED WORK

The study watershed consists of the drainage areas contiguous to the Chattahoochee River below West Point Dam and above the Walter F. George Reservoir. Nine dams along this highly regulated river between West Point and Columbus provide power, water supply, fishing and recreational uses. The River in this area divides Georgia from Alabama and contains growing urban centers along the I-85 corridor encompassing the cities of LaGrange, West Point and Opelika. The study area plays a significant position as a model for interstate water resource coordination on water quality and quantity issues.

Metropolitan Columbus (consisting of Columbus, Phenix City and Fort Benning) located in the center of the study area is growing to the north along I-185, east along US 80 and north along US 431. Much of this growth is within the watershed forming the source water for the areas drinking water supplies. Assessment and protection of the source waters is a major goal of the study.

Columbus has implemented wet weather controls to correct discharges associated with 2600 acres of combined sewers in the older central business district of the city. These controls include a full-scale CSO technology demonstration program (ADF) that can be operated at different quality levels with alternative disinfection methods. A second major goal of the study is to measure the health of the watershed and reactions to wet weather stresses to assess control effectiveness and compliance with water quality standards and beneficial uses. A basic determination of the ADF CSO control concept is matching levels of control with wet weather variations.

The ADF study was initiated in the spring of 1996; the watershed study was initiated in November of 1997. Both projects are scheduled to be complete by the end of 1999. Data collection is scheduled to be complete by the summer of 1999. The ADF project is being conducted parallel to and integral with the watershed study.

Current knowledge of water quality in this region of the Chattahoochee River can be found from several sources, including the US Geological Survey's National Water-Quality Assessment (NAWQA) Program and the Georgia Environmental Protection Division's (EPD) Chattahoochee River Management Plan. Other ongoing studies associated with the Apalachicola-Chattahoochee-Flint Rivers Tri-State Compact address both water quality and quantity issues.

EXPERIMENTAL DESIGN

The following hypotheses are being tested in the Middle Chattahoochee River Watershed Study:

1. Wet weather loadings from a watershed can be measured by time series water quality probes and correlated with parallel discrete bottle sampling and constituent analysis to provide a means to use water quality probes and flow to measure event-based and long term watershed contributions or changes in water quality parameters as a result of watershed controls or disturbances.
2. Wet weather watershed loading rates can be expressed as a function of antecedent conditions, runoff volume, time and other wet weather variables providing a sub-watershed loading rate relationship.
3. Pollutant loading, hydrologic parameters and event statistics can be used to quantify annual contributions and load reduction associated with a control performance.
4. Loading rate relationships can be used to calibrate BASINS model with respect to sub-watershed load generation.
5. In-stream probe and discrete sampling can be used to calibrate BASINS water quality segment modeling with respect to source integration and parameter decay.
6. Performance relationships, design criteria and costs can be developed for particulate removal and disinfection CSO treatment technologies.

Statistical significance and correlation reliability will be evaluated with respect to 95 percent confidence limits. Other tests for significance will include event and multi-event analysis for normality, ratios to mean, reliability of mean and trends in mean. If the hypotheses prove to be correct the methodologies developed in this study can be used by other practitioners to quantify wet weather loads, to provide measurements for watershed assessment studies, prepare TMDL allocations and to evaluate wet weather controls and benefits. Methodologies include both BASINS modeling and spreadsheet approaches.

Where certain hypothesis do not meet the quality objectives, then other methods will have to be derived to accomplish these project objectives. Statistical measurements and graphical analysis of data will be used to assess significance of the various relationships for the many water quality parameters attempted in this project. Many relationships will not be valid for the anticipated application. However, if normality is found in the event series and/or the multi-event data, probabilistic modeling may be an alternative method of achieving the project goals. Where quality objectives can not be met, conclusions will be attempted.

METHODS

Watershed measurements within the study area include stream flow, rainfall, water quality, aquatic biology, habitat and water body uses. Measurements are being made during dry and wet weather periods for the various seasons of the year for 16 sub-watersheds and 8 river monitoring stations and 16 locations both upstream and downstream of various CSO treatment technologies. Water quality measurements include pathogens, nutrients, organics, and metals. Sampling includes 10 wet weather events, 5 diurnal events, and 5 subsequent-to-rain events. Aquatic biology monitoring includes biannual fish and quarterly invertebrate measurements. Habitat includes physical environment descriptions and survey data. Use measurements will include field and public surveys and interviews conducted during different seasons of the year.

Water quality, flow and rainfall measurements will be used to calibrate spreadsheet and continuous record BASINS modeling. Modeling will be conducted to determine annual and event-based wet weather loads, water quality from different land uses and the integration of wet weather loadings for determination of compliance with water quality standards. Wet weather monitoring and modeling results will form the baseline for watershed management plans for the various sub-watersheds in the study area.

Flow measurements are being made using Chattahoochee River USGS Gauging Stations at West Point and at Columbus and the project gage in the tailrace from Oliver Dam. Flows in the creeks being monitored are being measured from calibrated stage-discharge relationships. Flows at the two CSO facilities and at the POTW's are also monitored. Flows calculated from Georgia Power turbine data are being evaluated with respect to the Project gage. River cross-sections and velocity profiling are being made at different flow and stage conditions.

All sampling is conducted using 24-bottle discrete samplers, arranged to take multiple samples throughout an event for different constituents with differing preservative requirements. The bottle/analyses arrangements are different for the various installations to efficiently utilize the capacity of the wet chemistry laboratory. Sample bottle set-ups are prepared in accordance with the sampling matrix and labeled using a LIMS system.

Six water quality probes are being used throughout the watershed and at sampling stations to monitor six parameters, including temperature, pH, ORP, conductivity, dissolved oxygen, and turbidity. Continuous measurement data from the water quality probes will be used in conjunction with discrete samples taken at the sampling station locations to evaluate relationships between the probe readings and other water quality stress measurements. Probes will be placed at the river monitoring stations during the diurnal monitoring effort. Probes will be used to monitor plume movements. Diurnal changes in river flows and water quality will be measured at the different seasons of the year.

Associated with the source water assessment program, inventories of potentially hazardous contaminant sources will be developed and located. Time of travel data and contamination mechanisms will be developed to assess susceptibility of water supply intakes. Aerial photographs will be used to assist in this effort and to evaluate plume effects in the lakes and river.

The upper river section in the Columbus urban area of the watershed will be monitored to evaluate water quality and contributions from a CSO and a non-CSO urban area. This controlled river section is expected to yield data on the integration and decay of water quality parameters and separate biology impacts associated with the headwaters, the non-CSO and the CSO sources.

Watershed data collection began in June 1998 and will continue through 1999. The first set of data evaluations for peer review and dissemination is scheduled in May 1999.

CONCLUSIONS

The ADF findings indicate that wet weather water quality parameters vary with respect to runoff volume (event size) and dry weather antecedent conditions defining predictable loading relationships for the watershed (Boner, 1997). The CSO's have been found to represent a system build-up and flush-out phenomenon. Build-up can be correlated with antecedent conditions. Runoff volume can in turn be correlated with the total load.

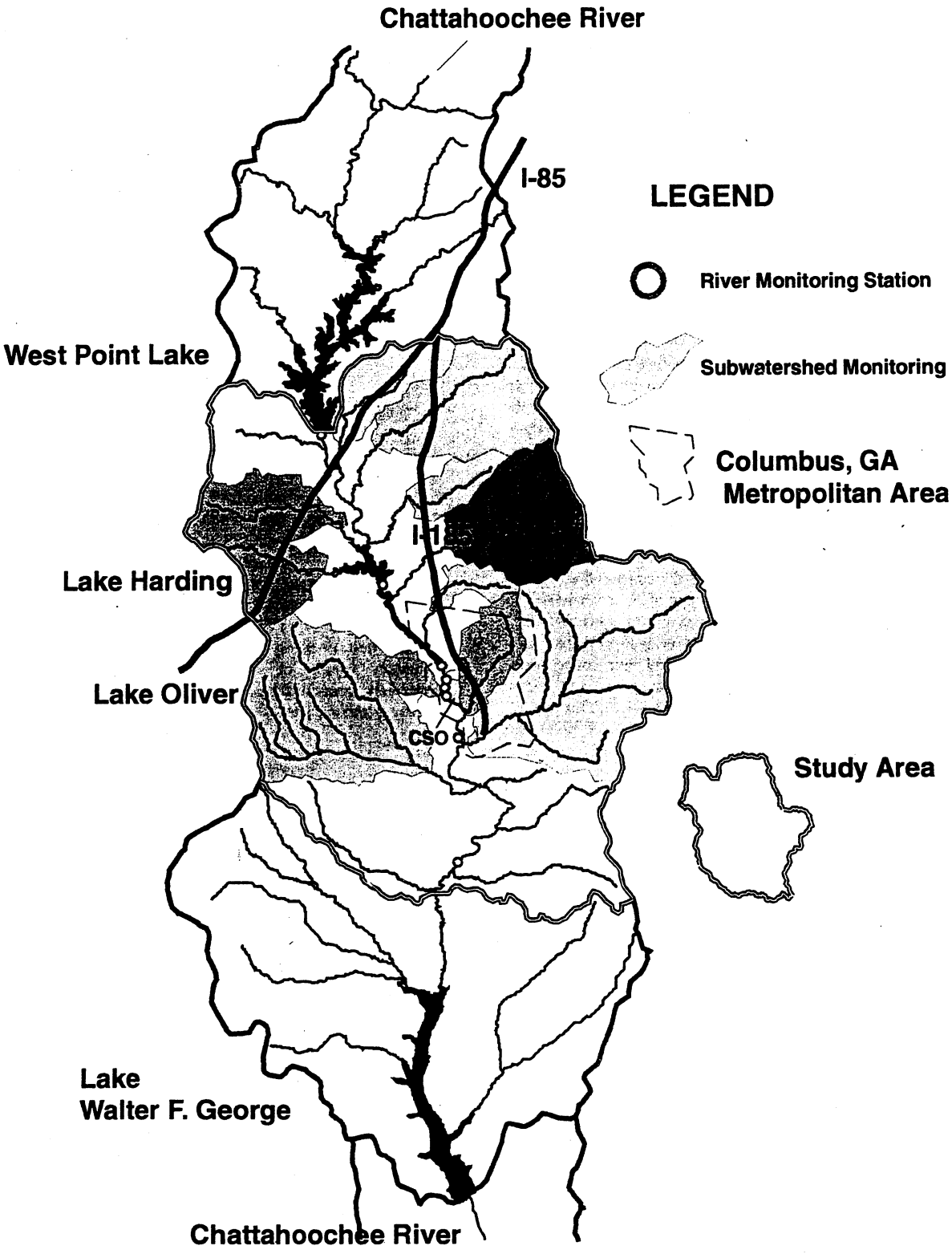

Figure 1. Middle Chattahoochee Watershed study area showing water quality and aquatic biology monitoring locations.

In terms of the annual distribution of pollutant loads, the smaller more frequent events causing system flushing are the major contributors to the annual total. Accordingly, controls for the smaller more concentrated wet weather flows result in cost-effective means to maximize constituent removals (Boner, 1998). The watershed data is being evaluated in a similar manner as the ADF to develop loading rate relationships for use in spreadsheet analyses and for calibrating the BASINS water quality model.

Event occurrence data coupled with rainfall/runoff functions developed for the ADF is being used with the loading rate relationships to develop design curves for assessing cost-effective control levels. Similar to the ADF, control level functions will be evaluated for various pollutants for each sub-basin in the watershed. If successful Control level functions can be used to evaluate management measures in watershed protection programs.

The wet weather control technologies and measurement methodologies developed in Columbus, Georgia will play a key role in the continued search for more economical and accountable approaches to addressing water quality issues in the watershed. The findings and economic analysis indicates that very significant savings can be achieved over conventional technologies that have been used in estimating national costs for CSO programs (Arnett, 1998). Similar success is anticipated for stormwater and non-point watershed management measures.

DISCUSSION

Expanding communities in Georgia are beginning to experience the requirements of watershed assessment and protection involving urban stormwater controls and leaking infrastructure repairs in order that wastewater treatment plant expansions can be permitted. The TMDL allocation requirements by states and EPA will begin to impose control levels for CSO's and SSO's (sanitary sewer overflows) and stormwater and non-point contributions to watershed impairments.

The Federal Clean Water Act requires the establishment of TMDL's and allocations for water quality limited stream segments considering all contributing sources and in-stream conditions. The TMDL allocation is made considering a number of factors including:

- Technical and programmatic feasibility
- Cost-effectiveness
- Enforceability
- Relative contributions

The sampling and quantification methodologies including a calibration techniques for EPA's BASINS model developed in the Middle Chattahoochee River Watershed Study will provide the means to cost-effectively quantify watershed management measures and delineate feasible and enforceable TMDL allocations.

ACKNOWLEDGEMENTS

The technology demonstration and watershed study sponsors include the USEPA, Georgia Environmental Protection Division, Alabama Department of Environmental Management, Columbus Water Works, Mead Corporation, and Georgia Power. In-Kind services are being provided by the Columbus State University, the Columbus Water Works, and community volunteer groups including the River Kids, Alabama Water Watch, Georgia Adopt-A-Stream, and both the Boy and Girl Scouts of America. Peer review coordination is being provided by the WERF; the voluntary efforts of the peer review team are graciously acknowledged. EPA is coordinating the quality assurance process.

LITERATURE CITED

Arnett, C.J., M. Boner, 1998. Columbus, Georgia, Wet Weather Demonstration Programs. WEFTEC '98, Water Environment Research Foundation, Conference Workshop #112, Saturday, October 3, 1998, pp. 17-35.

Boner, M., P.K. Gurney, 1997. Columbus, GA CSO Load Characterization and Design Application. In: Water Environment Research Foundation Wet Weatherx, Volume 2 Issue 1, pp. 3-7.

Boner, M., P.K. Gurney, 1998. Technology Performance fo Solids Separation and Disinfection. In: Water Environment Research Foundation Wet Weatherx, Volume 3 Issue 1, pp. 4-9.